X036/701

NATIONAL QUALIFICATIONS 2008

WEDNESDAY, 4 JUNE
1.00 PM – 4.00 PM

TECHNOLOGICAL STUDIES
ADVANCED HIGHER

100 marks are allocated to this paper.

Answer **all** questions in Section A (60 marks).

Answer **two** questions from Section B (20 marks each).

Where appropriate, you may use sketches to illustrate your answer.

Reference should be made to the Advanced Higher Data Booklet (2006 edition) which is provided.

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SECTION A

Marks

Attempt all the questions in this Section. (Total 60 marks)

1. The prototype wooden seat supports for the canoe shown in Figure Q1(*a*) can be considered to be built-in beams.

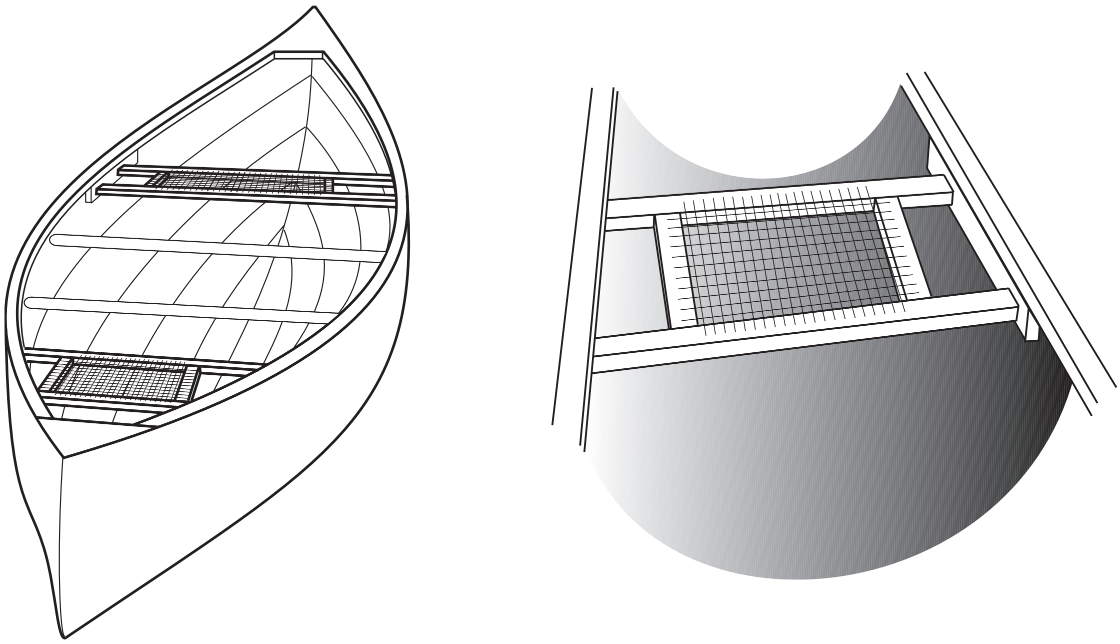


Figure Q1(*a*)

Each seat support is made from wood of rectangular section, and breadth 25 mm. The maximum design load on each seat support is estimated to be a point-load of 2 kN as shown in Figure Q1(*b*). The maximum allowable deflection is 1·0 mm.

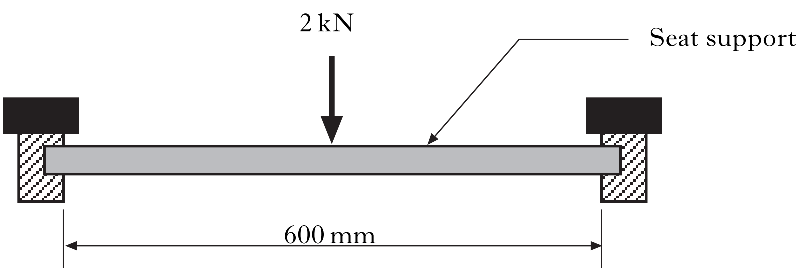


Figure Q1(*b*)

Calculate, for the loading shown:

(*a*) the maximum bending moment; **2**

(*b*) the minimum depth of the beam section; **4**

(*c*) the maximum stress. **3**

(9)

[Turn over

Marks

2. A domestic "plug-in" air freshener is shown in Figure Q2(*a*).

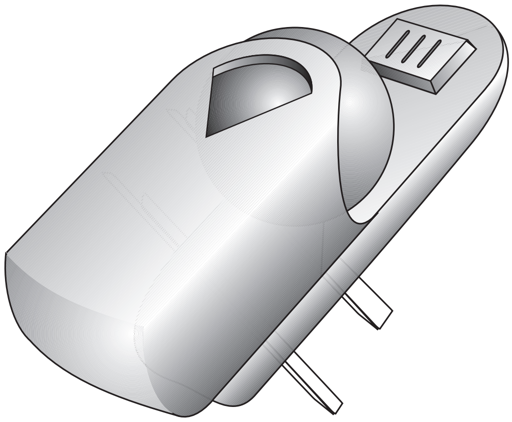


Figure Q2(*a*)

The air freshener releases a dose of fragrance into a room at regular intervals by evaporating a small reservoir of perfume, using a small heater and fan. The electronic control circuit is shown in Figure Q2(*b*), opposite.

(*a*) Explain the operation of the electronic control circuit in terms of sub-systems A, B, C and D. **4**

(*b*) Calculate, for the values shown, the time interval between the start of one fragrance release and the start of the next release. **4**

(8)

2. (continued)

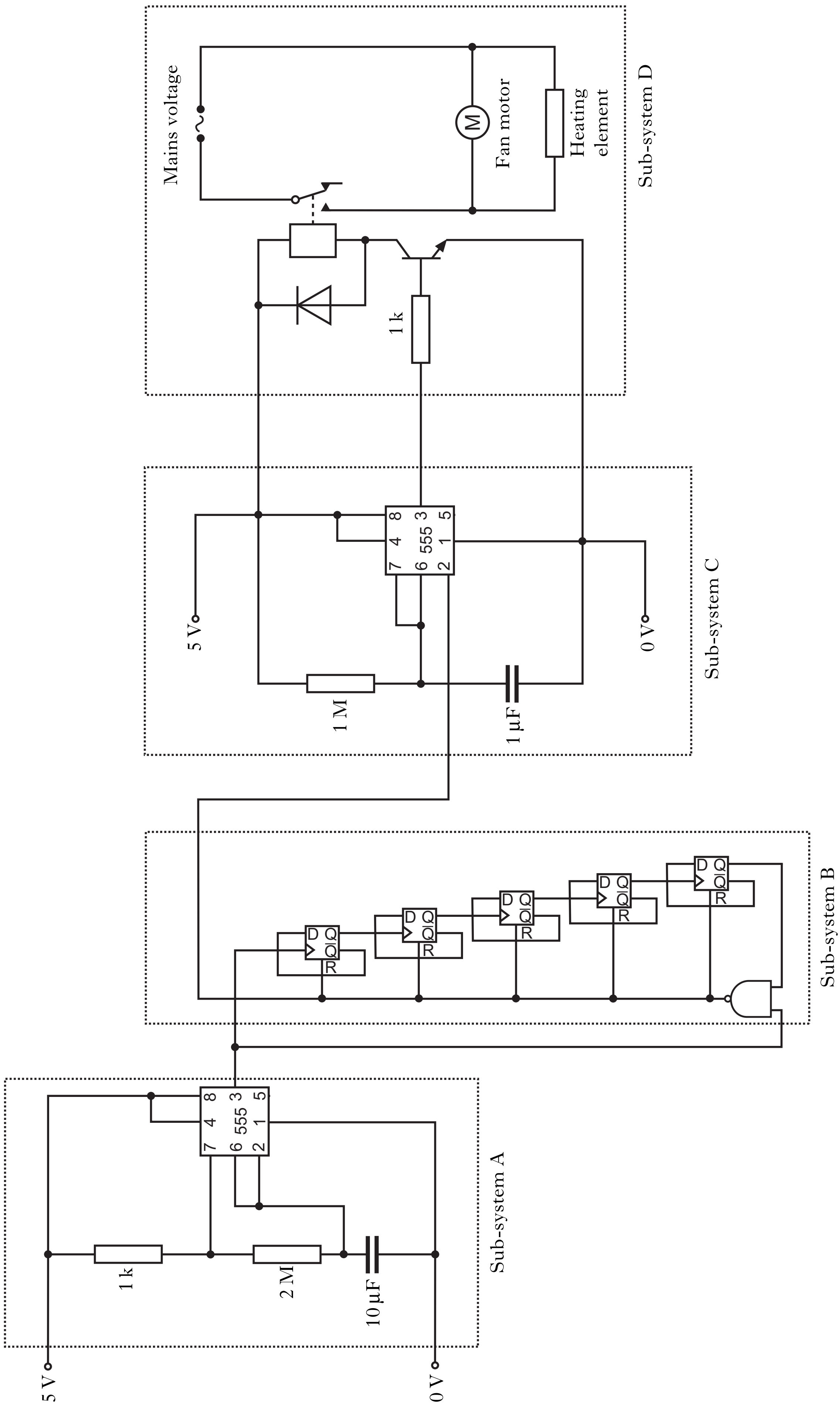
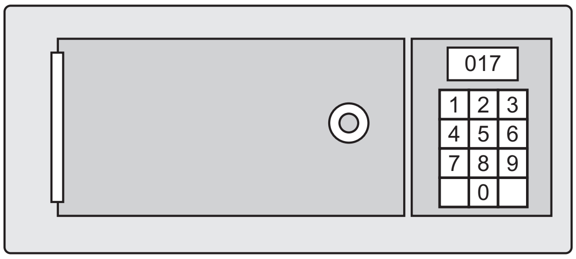


Figure Q2 (*b*)

3. The block diagram for a lock on a room safe in a hotel is shown in Figure Q3(*a*). A 3-digit security code is entered via the keypad, which is connected via an encoder to a microcontroller. When the correct code has been entered, the solenoid unlocks the door. If an incorrect code is entered, the microcontroller operates a buzzer for two seconds and also prevents any further entry attempts for 15 minutes.



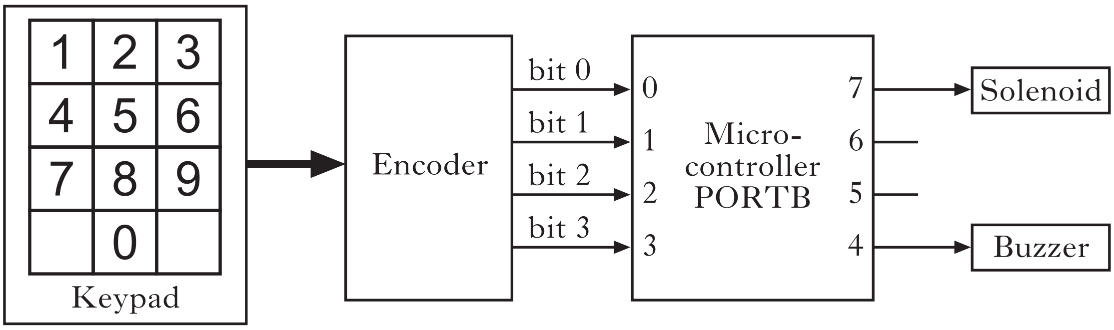


Figure Q3(*a*)

Write, in assembler code, the part-program to satisfy the flowchart shown in Figure Q3(*b*), opposite.

You may assume the file registers DIGIT1, DIGIT2 and DIGIT3 have been set up and contain the correct entry code values. The file register ERRORCOUNT has also been set up. The sub-procedure *getdigit* reads the encoded value entered on the keypad, and stores it in the Working Register (W).

The sub-procedure *wait* provides a time delay of 0·1s times the value in W, and the sub-procedure *delay* produces a time delay of 15 minutes when called. TRISB has been initialised.

(9)

3. (continued)

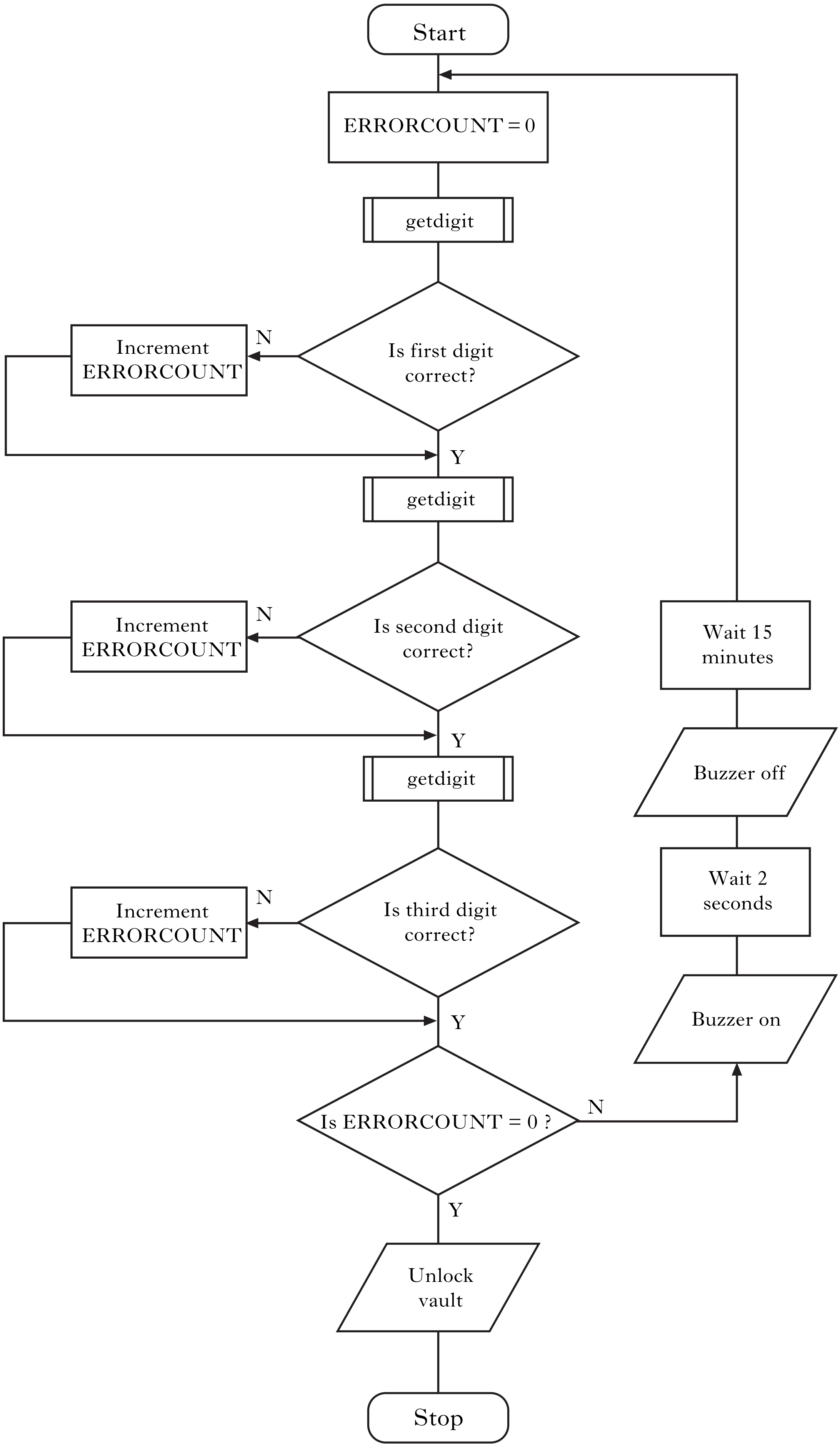


Figure Q3(*b*)

[Turn over

Marks

4. A lecturer has designed a system to demonstrate the function of two operational amplifier circuits. The first circuit is a Wein bridge oscillator as shown in Figure Q4(*a*).

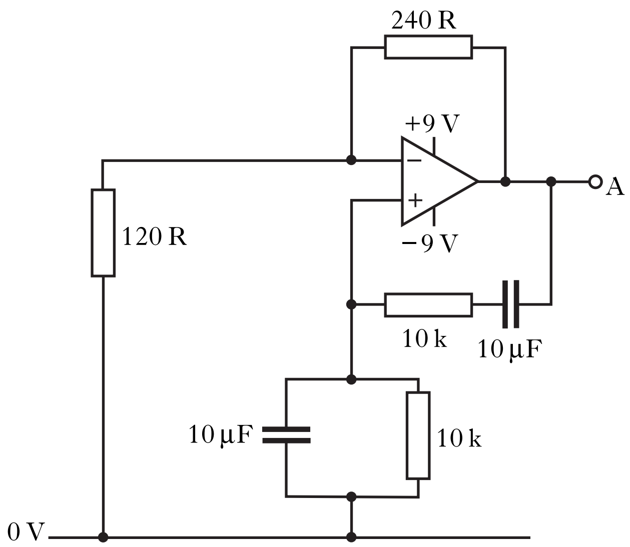


Figure Q4(*a*)

(*a*) For the oscillator circuit shown in Figure Q4(*a*):

(i) sketch the shape of the output waveform at A; **1**

(ii) calculate the frequency of the output signal at A. **2**

The waveform produced at A is fed into the Schmitt trigger circuit shown in Figure Q4(*b*).

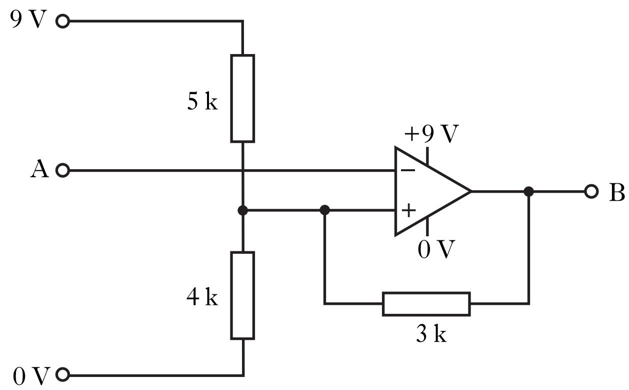


Figure Q4(*b*)

(*b*) (i) Sketch the output waveform at B. **1**

(ii) Calculate the switch-off and switch-on values for the circuit. **3**

(7)

5. The "cruise control" in a car is an automatic system for maintaining a constant speed without the driver needing to use the accelerator pedal. A control diagram for such a system is shown in Figure Q5.

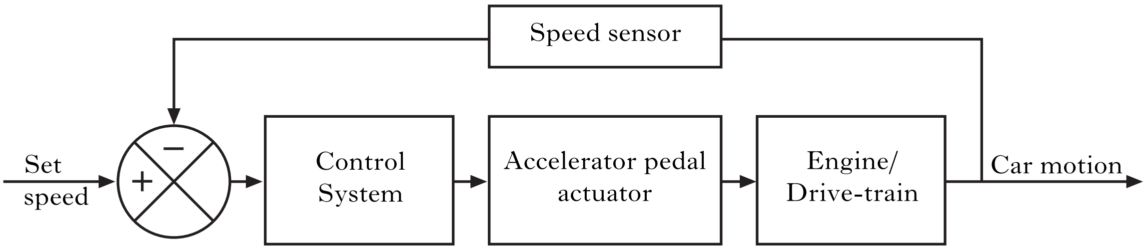


Figure Q5

(*a*) Sketch, on **Worksheet Q5**, the responses of the actual car speed to the step-change in desired speed, for the following types of control system:

(i) Proportional control only, with low gain factor "K"; **1**

(ii) Proportional control only, with gain factor "K" set too high; **1**

(iii) Proportional, Integral and Derivative control. **1**

(*b*) State the effect of adding "Integral" to "Proportional only" control. **1**

(*c*) State the effect of adding "Derivative" to "Proportional only" control. **1**

(5)

[Turn over

6. The screen image of an ultrasound scanner is formed on a cathode ray tube (CRT), by firing a stream of electrons onto a fluorescent screen. The stream of electrons is guided by applying voltages to pairs of deflecting plates. A simplified arrangement is shown in Figure Q6(*a*).

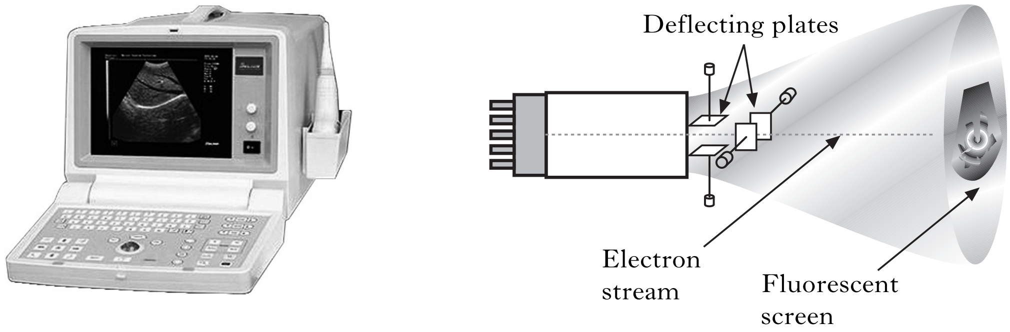


Figure Q6(*a*)

The voltage applied to one pair of deflecting plates causes the electron stream to scan across the screen horizontally, and has the waveform shown by Figure Q6(*b*). The ramp portion of the waveform is generated by an integrator circuit and the fly-back portion is achieved by discharging the capacitor via a transistor.

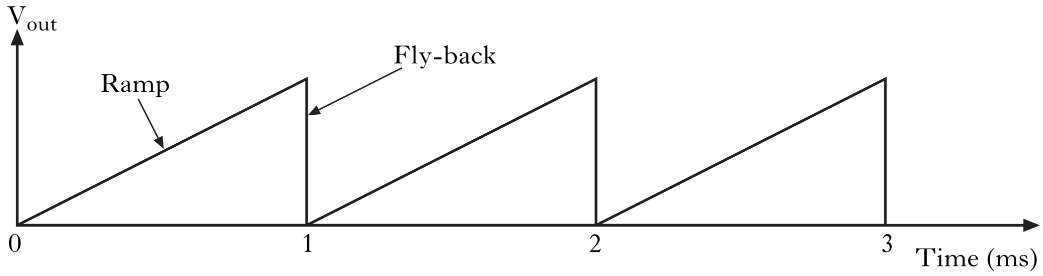


Figure Q6(*b*)

The waveform is generated by the circuit shown in Figure Q6(*c*).

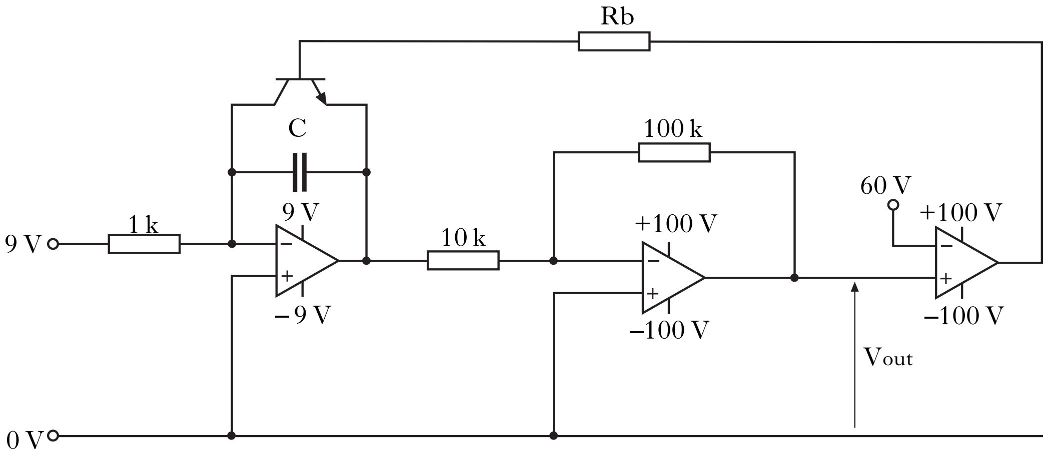


Figure Q6(*c*)

The comparator reference voltage is set at 60 volts.

(*a*) Calculate the capacitance of capacitor C. **3**

Marks

6. (continued)

The voltage applied to the **second pair** of deflecting plates causes the beam to move vertically in steps, and has the waveform shown in Figure Q6(*d*).

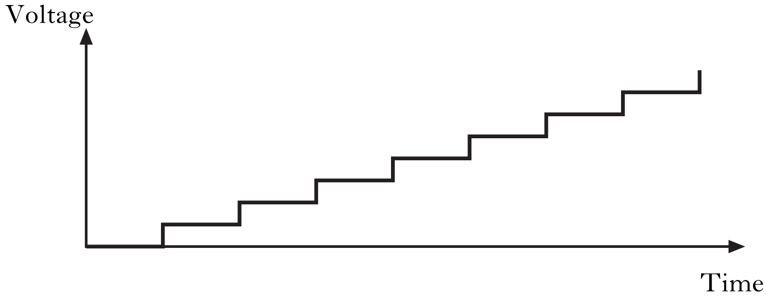


Figure Q6(*d*)

A simplified version of this stepped voltage can be produced by the 8-bit DAC shown in Figure Q6(*e*).

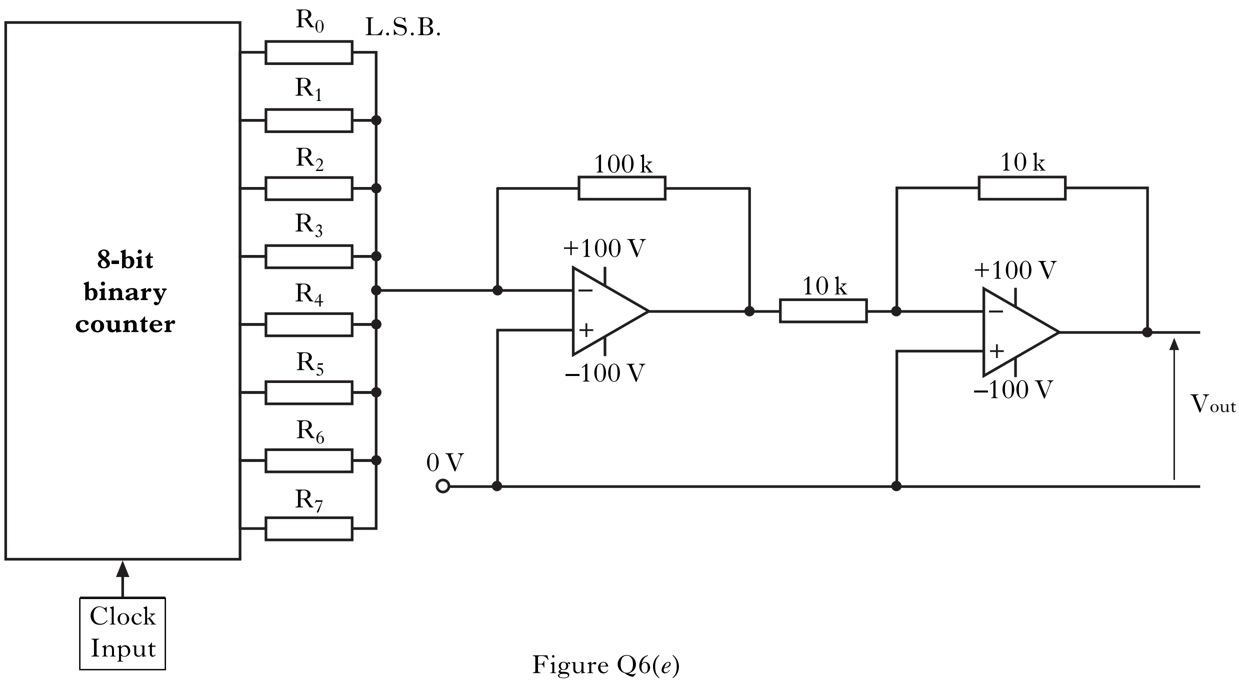


Figure Q6(*e*)

The binary counter outputs digital voltage levels of either 0 V or 5 V, and the maximum voltage to the deflecting plates (V_{out}) is to be 79·7 volts.

(*b*) Calculate the required values of R_0 through to R_7. **5**

(*c*) Calculate the output voltage V_{out} if the input to the DAC is 01101010. **1**

(9)

[Turn over

Marks

7. The hair straighteners shown in Figure Q7(*a*) are controlled by a microcontroller. One of three heat settings can be selected on the 3-position dial shown. Each heat setting value is represented by an 8-bit byte and is transferred serially to the microcontroller via pin 3. It is then stored in a register file called SETTING.

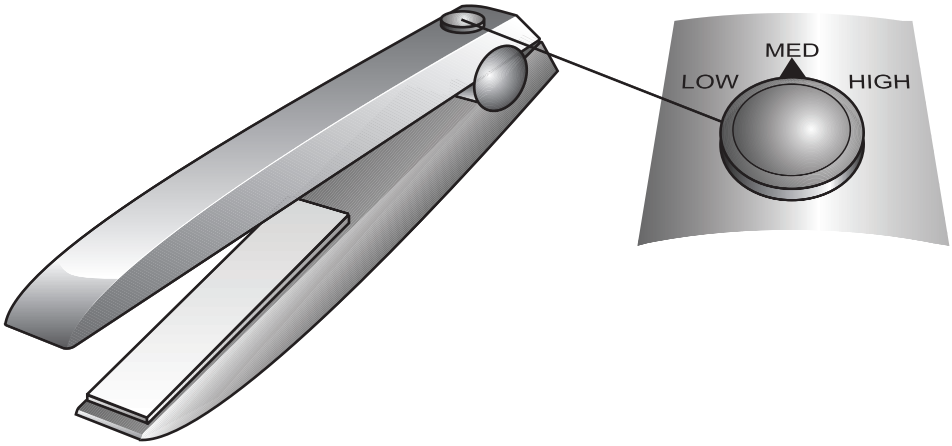


Figure Q7(*a*)

(*a*) State one advantage of transferring the data serially to the microcontroller. **1**

The flowchart shown in Figure Q7(*b*), opposite, represents the sub-procedure *transfer* used to transfer the required heat setting value serially into the register file SETTING.

(*b*) Write an assembler code program for the sub-procedure *transfer*. Assume the register files COUNTER and SETTING are already set up. **4**

The microcontroller compares the value in SETTING with the "medium" heat setting byte. If the values are equal, the "medium" heat setting is used. If the value in SETTING is less than the "medium" heat-setting byte, the "low" heat setting is used, otherwise the "high" heat setting is used.

The microcontroller uses pulse-width modulation to control the heat setting in accordance with the mark and space times shown in the table below.

Heat setting	Heat-setting byte	Mark time (ms)	Space time (ms)
Low	00001000	5	3
Medium	00010000	8	3
High	00100000	12	3

(*c*) Write an assembler code program which will monitor the register file SETTING and will control the heating element according to the specification above. **8**

The heater is connected to output pin 5. The sub-procedure *pause* produces a time delay of 1 ms times the value in W. TRISB has been initialised. **(13)**

7. (continued)

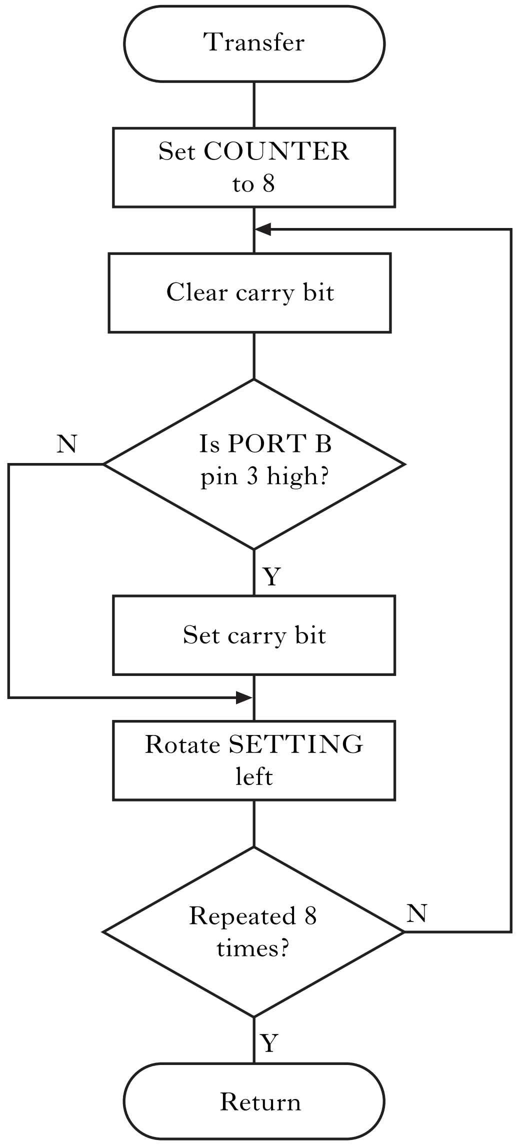


Figure Q7(*b*)

[*END OF SECTION A*]

[Turn over

Marks

SECTION B

Attempt any two questions in this section.

Each question is worth 20 marks

8. A turbo-prop aircraft is shown in Figure Q8(*a*).

Figure Q8(*a*)

A simplified diagram of the aircraft with its under-carriage down is shown in Figure Q8(*b*).

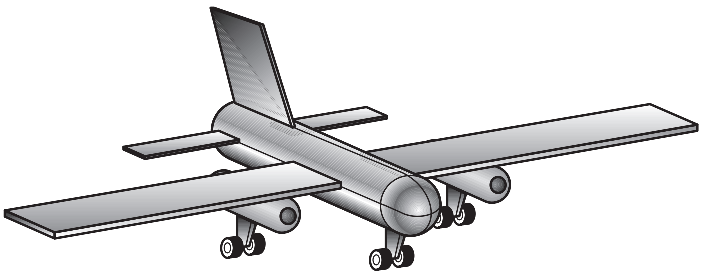


Figure Q8(*b*)

Each wing may be treated as a cantilever. **Worksheet Q8A** shows the free-body diagram of one wing whilst the aircraft is **parked on the ground**.

(*a*) Calculate the reaction moment M_R and the reaction R_{wheel}. **2**

(*b*) On **Worksheet Q8A**, complete the Shear-force diagram. Show significant values. **4**

Worksheet Q8B shows the Free-body diagram and the Shear-force diagram of one wing whilst the aircraft is **in flight**. Two uniformly distributed loads are shown; one is due to the weight of the wing (acting **down**), and the other is due to the upward thrust of the air providing "lift" (acting **up**).

(*c*) On **Worksheet Q8B**, complete the table of results and draw the Bending-moment diagram (show all working). **7**

8. (continued)

The landing-gear of the aircraft is controlled by a sequential control system as shown in Figure Q8(*c*).

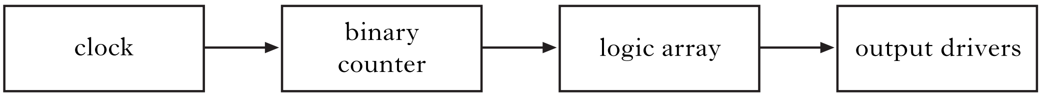


Figure Q8(*c*)

(*d*) Explain the function of each of the sub-systems shown in Figure Q8(*c*). **2**

The sequential control system controls three hydraulic valves for the opening and closing of 2 doors and the lowering of the under-carriage. The required sequence of operations for the landing-gear control is shown in the table below.

	Landing Gear		
Counter Output (CBA)	LH door valve	RH door valve	Under-carriage valve
000	0	0	0
001	1	1	0
010	1	1	0
011	1	1	0
100	1	0	1
101	1	0	1
110	1	0	1
111	DISABLE BINARY COUNTER		

(*e*) Write a boolean expression for the RH door valve, in terms of C, B and A. **1**

(*f*) Draw, on **Worksheet Q8C**, the logic array required to control **all** the outputs, and to disable the binary counter. **4**

(20)

[Turn over

Marks

9. During installation, one type of oil-drilling platform has its base attached to the sea bed. The platform modules may then be lifted from a container ship onto the base using a ship-mounted crane as shown in Figure 9(*a*).

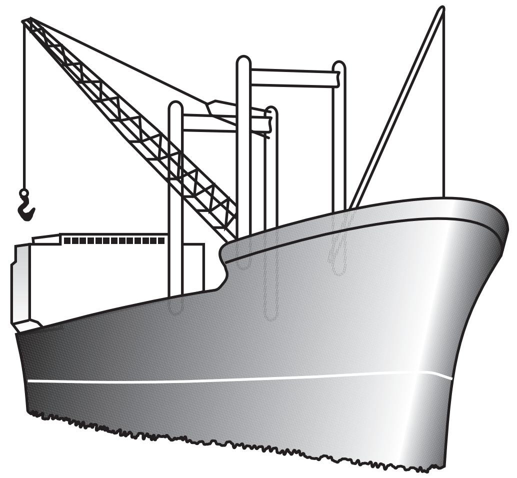


Figure Q9(*a*)

Figure Q9(*b*) shows the end section of one crane jib.

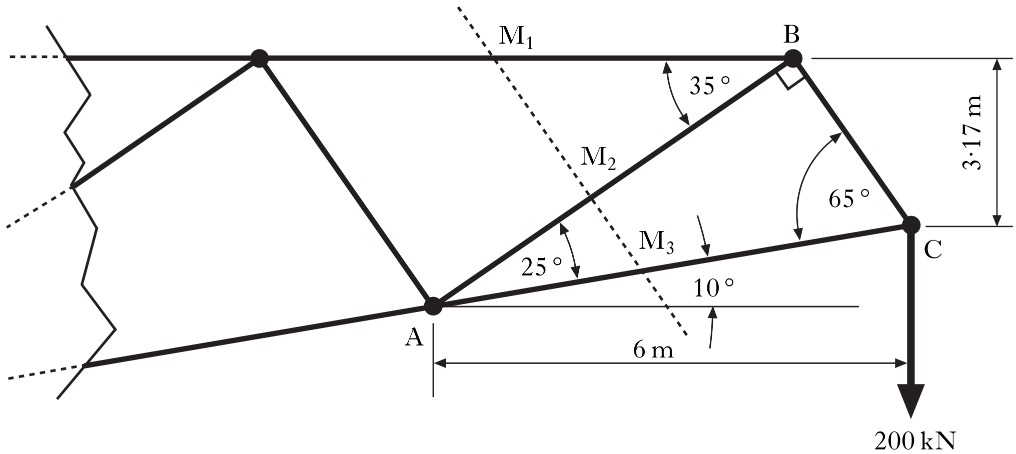


Figure Q9(*b*)

(*a*) Calculate, using the ***method of sections***, the **magnitude** and **nature** of the forces in members M_1, M_2 and M_3. **10**

9. (continued)

As the crane moves a module, the ship is balanced by the use of ballast tanks. The ballast tanks can be either filled or drained of sea-water by a pump and a network of pipes and servo-valves. The valve shafts are driven by a servo-motor. A simplified diagram of the servo-valve is shown in Figure Q9(*c*).

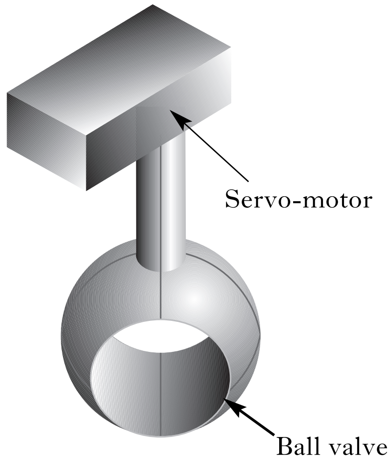


Figure Q9(*c*)

Inputs	PORT B Pins	Outputs
	7	
	6	
	5	
	4	Servo-valve
	3	
"Fully-open" switch	2	
"Half-open" switch	1	
"Fully-closed" switch	0	

The table above shows the connections to the microcontroller, which controls the servo-valve to the following specification.

- Pin 4 of PORTB of the microcontroller is pulsed to control the servo-valve.
- A mark of 0·50 ms and space of 20 ms produces a servo-motor shaft position of 0 °.
- A mark of 1·50 ms and space of 20 ms produces a servo-motor shaft position of 90 °.
- A mark of 2·5 ms and space of 20 ms produces a servo-motor shaft position of 180 °.
- The valve is fully open when the servo-motor shaft is at the 45 ° position.
- The valve is fully closed when the servo-motor shaft is at the 135 ° position.
- The valve can be fully open, half open or fully closed, depending on which one of three switches is operated.

(*b*) Write an assembler code program that will either fully open, half open or fully close the ball valve, depending on which switch is operated. Assume that all PORTB pins have been initialised.

Plan your program using a flowchart or other suitable method.
Two delay sub-procedures are available: *short* provides a time delay of 10 µs times the value in W, and *pause* provides a time delay of 1ms times the value in W. TRISB has been initialised.

10

(20)

[Turn over

10. The countdown timer shown in Figure Q10(*a*) can be set to count periods ranging from 1 to 9 minutes, in 10-second intervals. When a number of full minutes has been set, a "bleep" sounds for 0·2 seconds. As the countdown proceeds, the number of full remaining minutes is displayed as a digit on a 7-segment display.

In addition, at the start of each full minute, 6 LEDs are illuminated; one extinguishes each 10 seconds until the minute has elapsed, and this sequence is repeated for each minute. When all of the minutes have elapsed, a "bleep" sounds for 2 seconds.

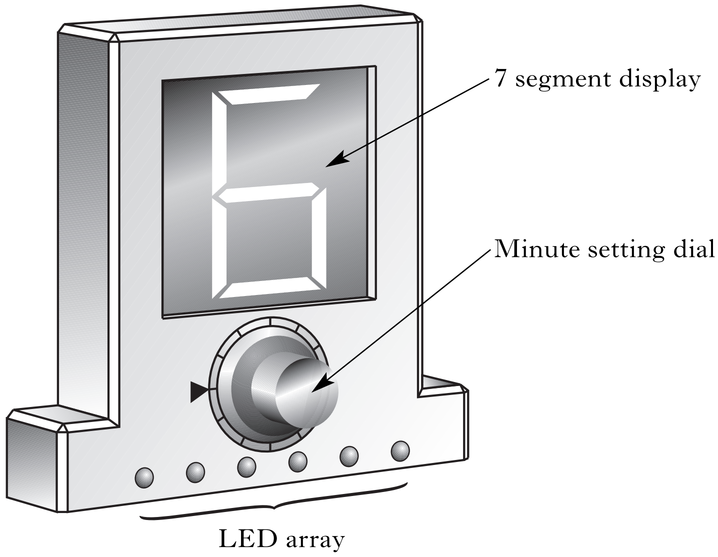


Figure Q10(*a*)

The timer is controlled by a microcontroller and a number of bistable circuits as shown in Figure Q10(*b*).

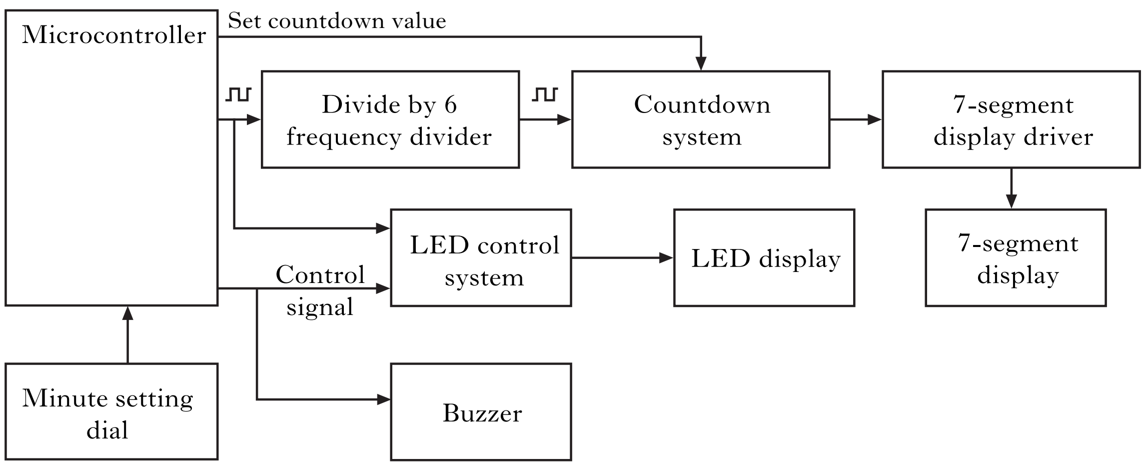


Figure Q10(*b*)

As the timer display only requires a clock pulse every 60 seconds a "divide-by-6" frequency divider constructed from J-K bistables is used to clock the countdown counter.

(*a*) On **Worksheet Q10A**, complete the circuit for this function. **3**

10. (continued)

The 6 LEDs are controlled by D-type bistables which can be preset (S). The circuit is clocked once every 10 seconds. At the start of each minute all LEDs are preset high by the control signal which then goes low. On each clock pulse one LED goes low in sequence starting from the left until they are all low.

(*b*) (i) On **Worksheet Q10B**, complete the circuit to achieve this function. **3**

(ii) State the name of this circuit. **1**

The countdown function is achieved using J-K bistables (see **Worksheet Q10C**). Assume the count has already been set to 9 by the microcontroller and the circuit is ready to count down. The Preset (S) and Preclear (R) pins are "active high".

(*c*) (i) State the logic levels required at PORTB pins 7 – 4 in order to preset the value "9" in the countdown circuit. **1**

(ii) State the required logic level of pin 0 so that presetting can take place. **1**

(iii) On **Worksheet Q10C**, complete the J-K circuit to count down from 9 to 0 when it is clocked 9 times. **3**

The microcontroller controls the timer system as shown in Figure Q10(*b*). Its input and output connections are shown in the table below. When the count reaches zero a signal is sent to pin 2.

Inputs	PORT B pins	Outputs
	7	Bistable D setup
	6	Bistable C setup
	5	Bistable B setup
	4	Bistable A setup
	3	Buzzer/control signal
count-zero	2	
	1	Clock output
	0	Reset

When the program starts, the "number of minutes" setting is obtained using the sub-procedure *minset*. This value is then sent to the bistable-setup pins (via PORTB pins 7 – 4) to preset the bistables. The bistable-setup pins are then set low, and pin 0 is set to the correct logic level to allow the countdown to begin.

The LED bistable circuit is set high and a bleep sounded by making pin 3 high for 0·2 seconds. The clock output pin is then set high in a loop for 0·1 second every 10 seconds. This continues until pin 2 goes high, the buzzer is then set high for 2 seconds, and the program ends.

(*d*) Write an assembler code program which will produce the control described above. Plan your program using a flowchart or other suitable method. **8**

The sub-procedure *minset* puts a value into the top 4 bits of a register file DATA ready for direct transfer to PORTB. The sub-procedure *wait* provides a time delay of 0·1 s times the value in W. TRISB has been initialised.

(20)

[*END OF SECTION B*]

[*END OF QUESTION PAPER*]

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FOR OFFICIAL USE

X036/702

NATIONAL QUALIFICATIONS 2008

WEDNESDAY, 4 JUNE
1.00 PM – 4.00 PM

TECHNOLOGICAL STUDIES

ADVANCED HIGHER

Worksheets for Questions 5, 8(*a*), 8(*b*), 8(*c*), 10(*a*), 10(*b*) and 10(*c*)

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Date of birth
Day Month Year

Scottish candidate number

Number of seat

To be inserted inside the front cover of the candidate's answer book and returned with it.

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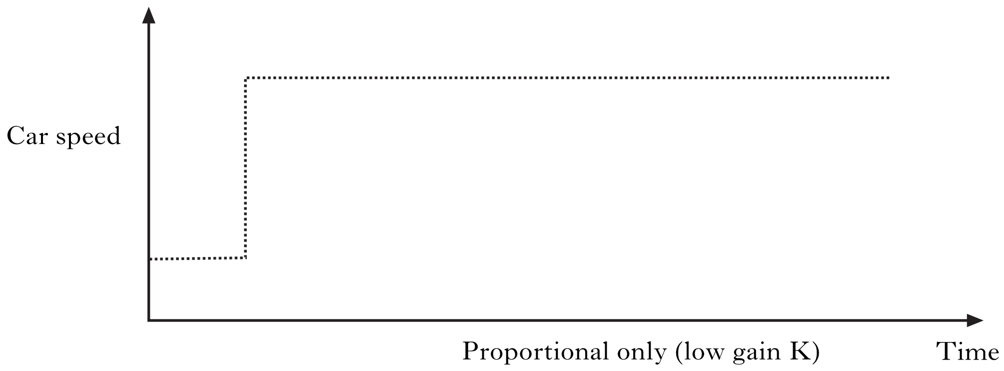
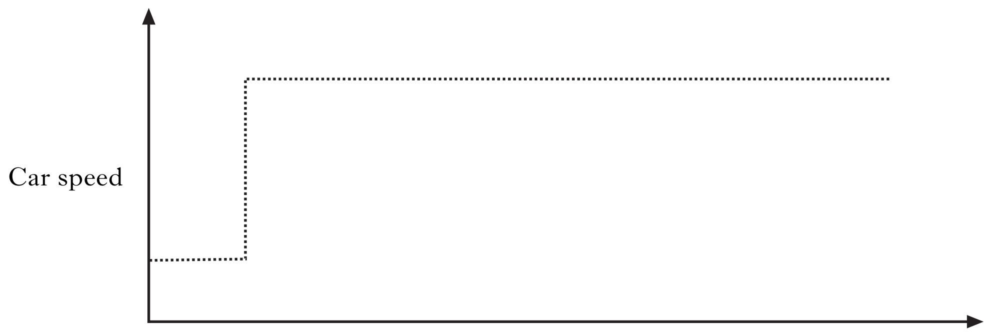
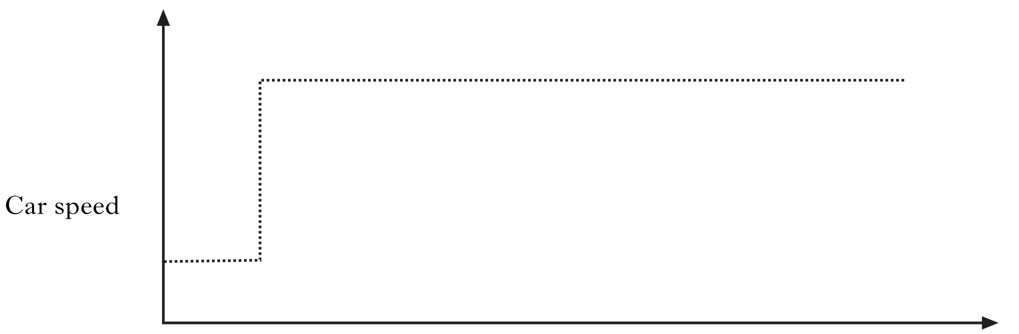
WORKSHEET Q5



Proportional only (low gain K)



Proportional only (gain K too high)



Proportional plus Integral plus Derivative

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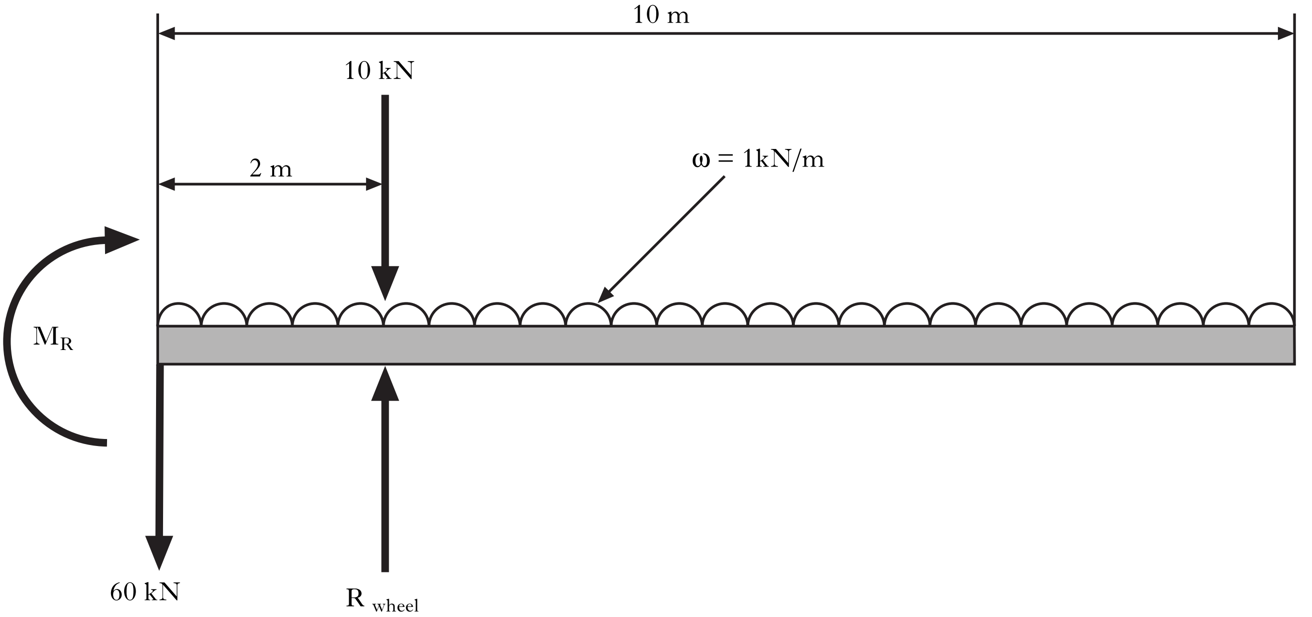
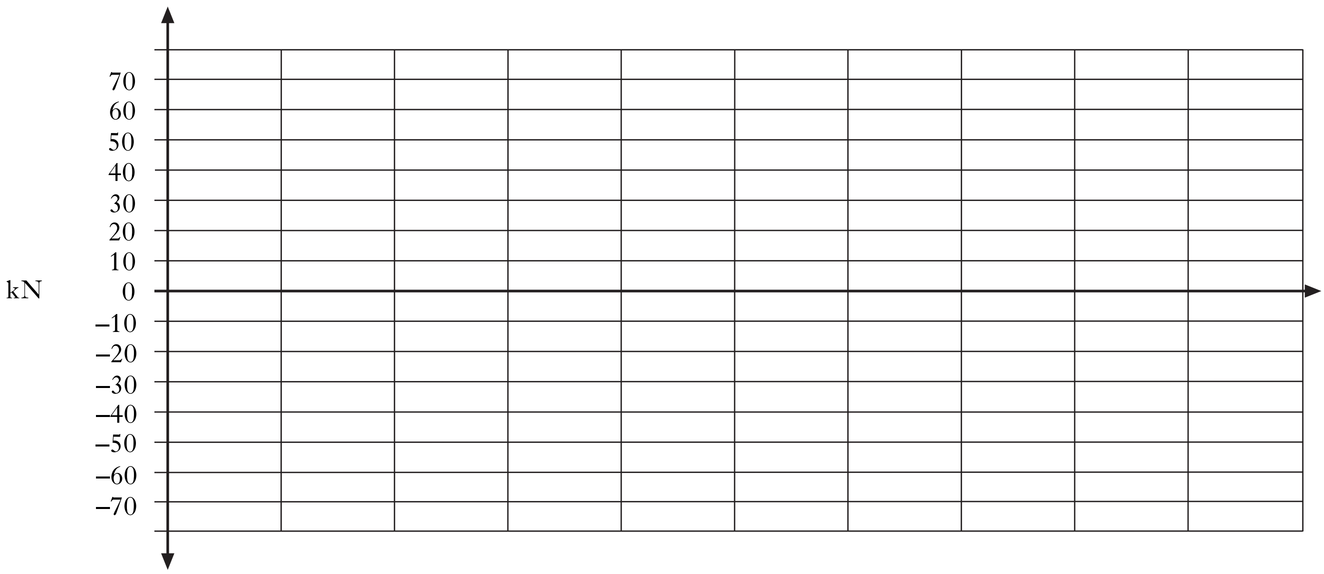
WORKSHEET Q8A (on ground)

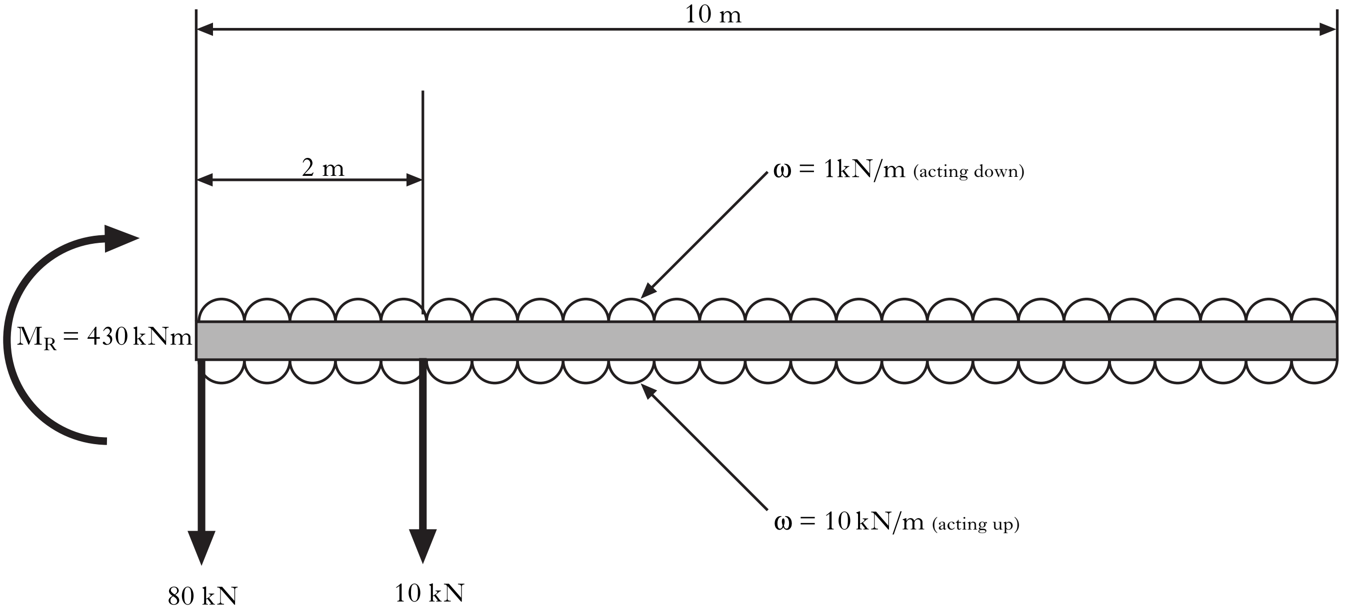


Free-body diagram

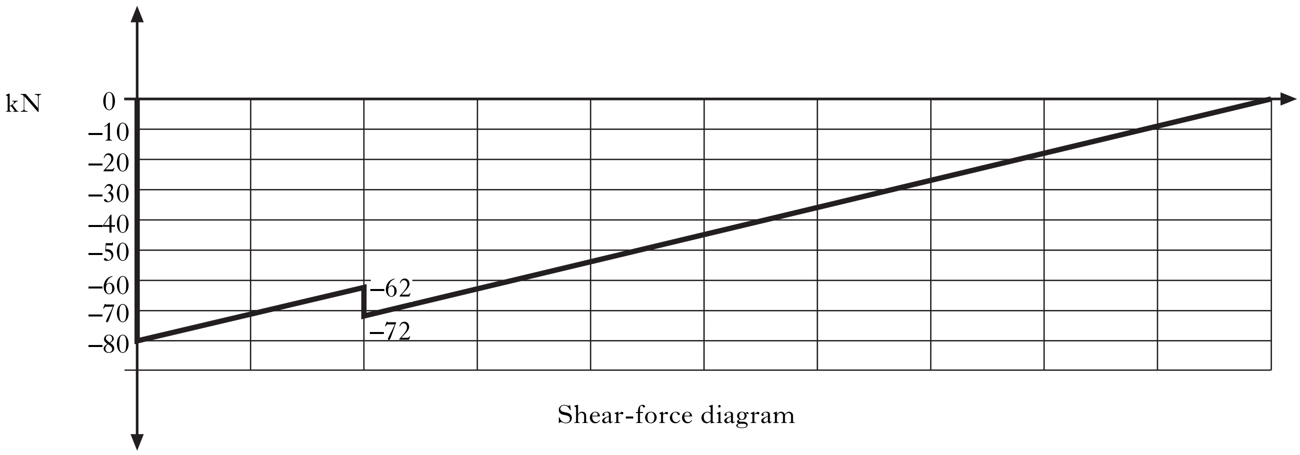


Shear-force diagram

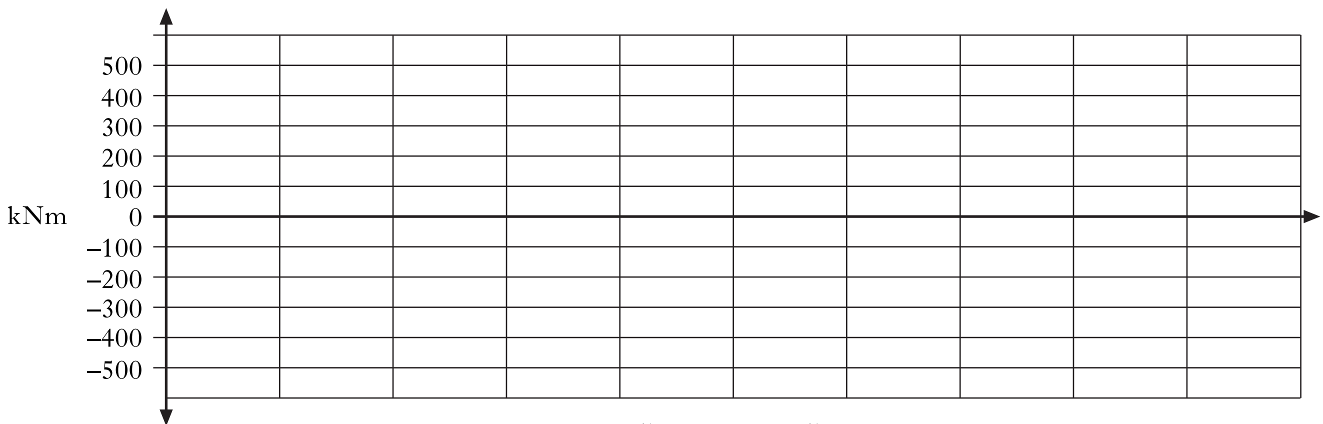
WORKSHEET Q8B (in flight)



Free-body diagram



Shear-force diagram



Bending-moment diagram

Distance from left end (m)	0	2	4	6	8	10
Bending moment (kNm)						

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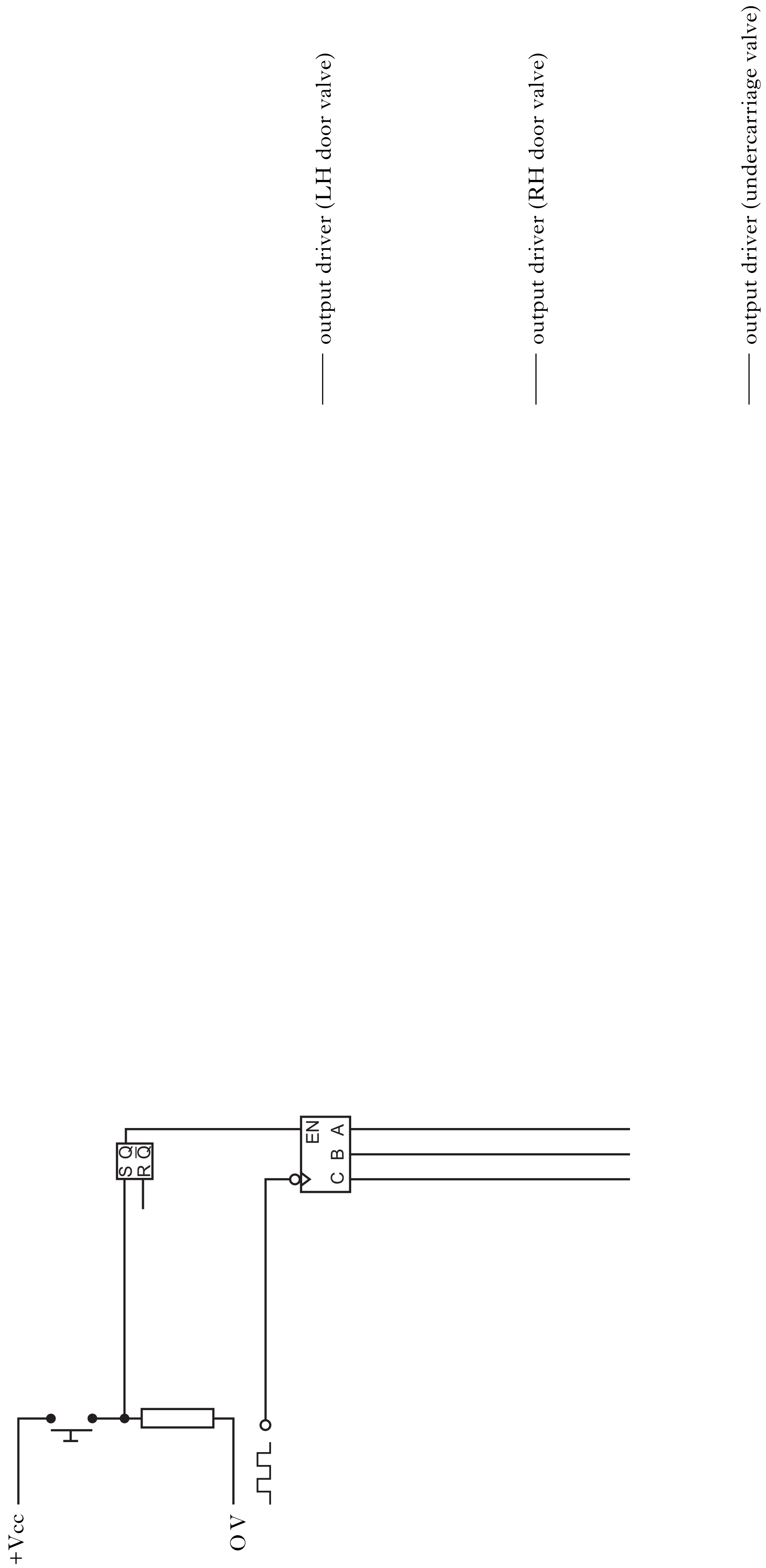
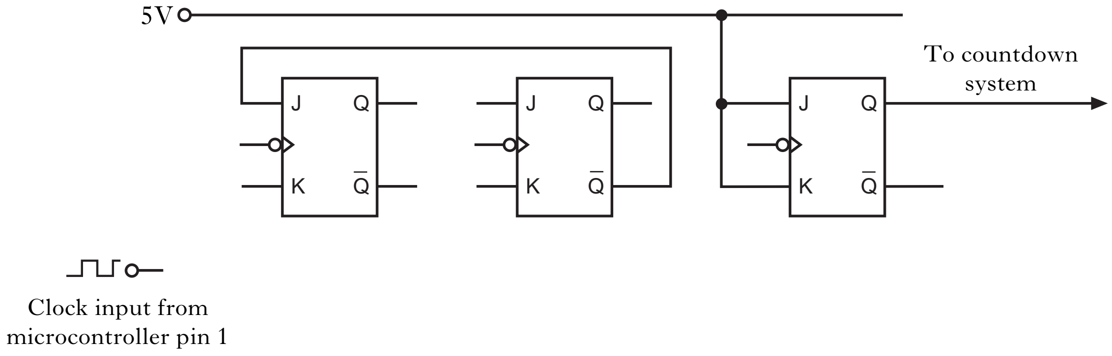
WORKSHEET Q8C

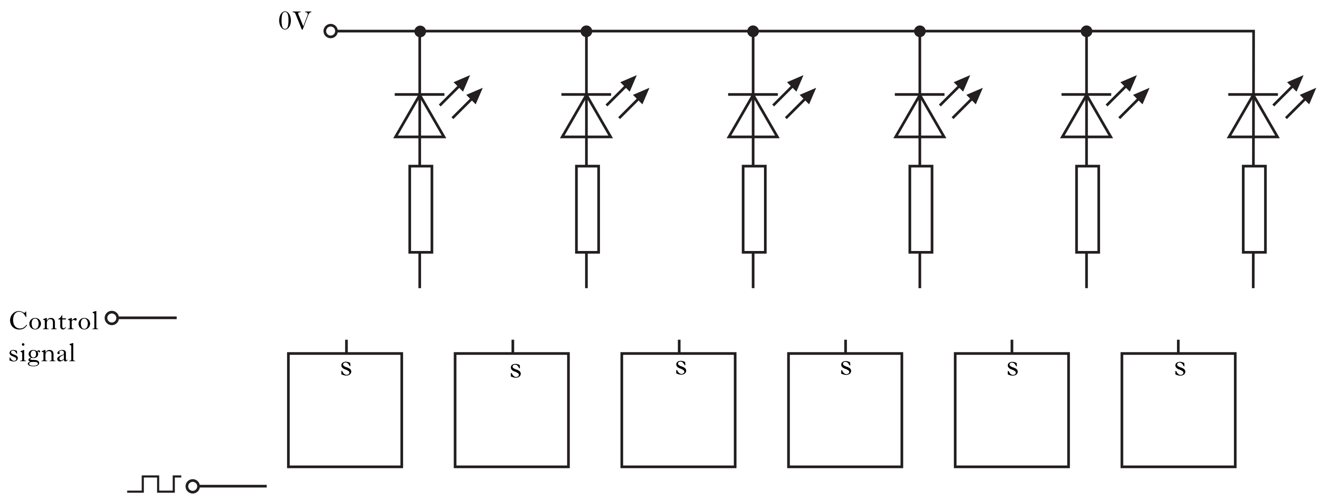


WORKSHEET Q10A



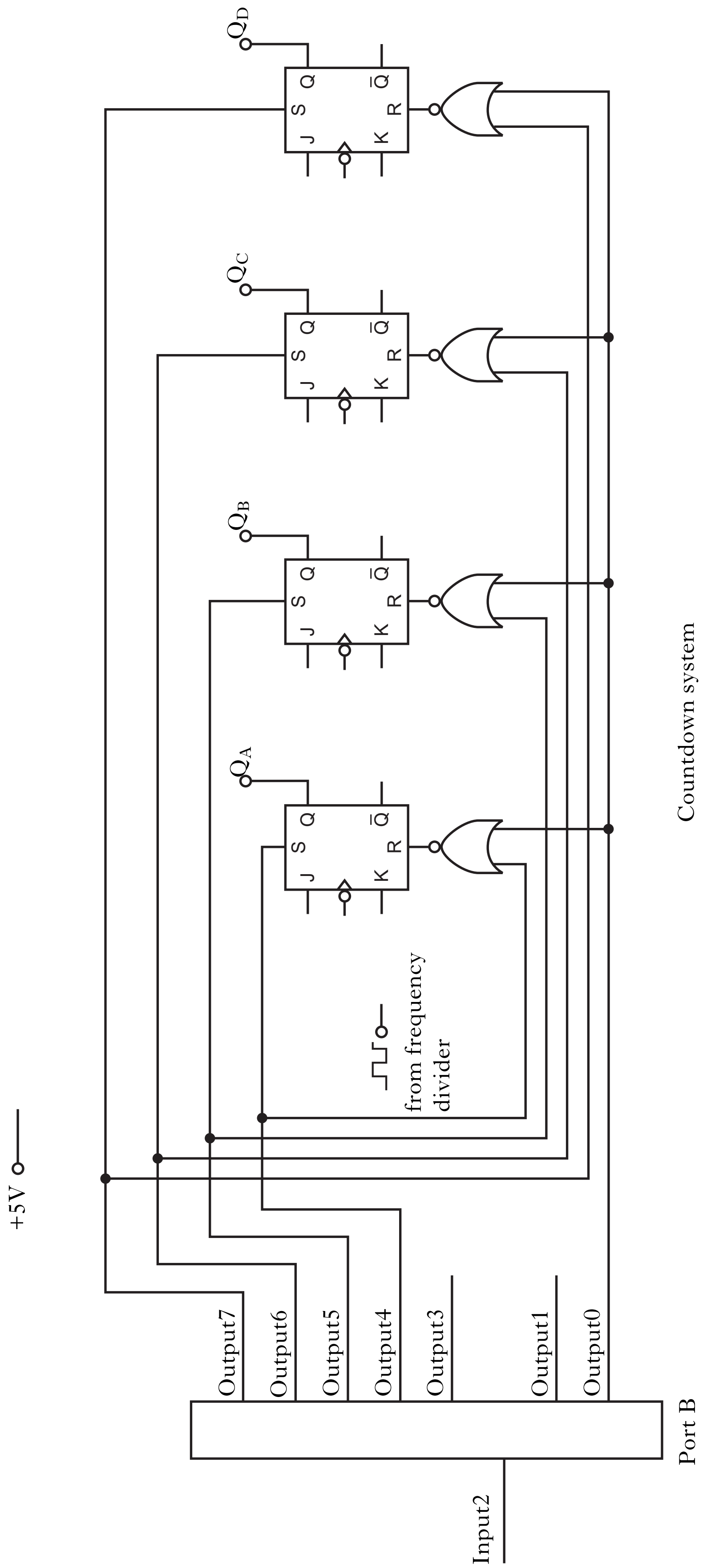
"Divide by 6" frequency divider

WORKSHEET Q10B



LED control circuit

[Turn over



[*END OF WORKSHEETS*]